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CHEMICAL AND METALLURGICAL TECHNOLOGIES, SUGGESTED TECHNIQUES FOR DETERMINING COURSES OF STUDY IN VOCATIONAL EDUCATION PROGRAMS.

BY- PETERSON, CLARENCE E.
OFFICE OF EDUCATION, WASHINGTON, D.C.

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DESCRIPTORS- *CURRICULUM DEVELOPMENT, *JOB ANALYSIS, OCCUPATIONAL CLUSTERS, EDUCATIONAL NEEDS, CURRICULUM PLANNING, *OCCUPATIONAL INFORMATION, TECHNICAL EDUCATION, *CHEMICAL TECHNICIANS, *ENGINEERING TECHNICIANS, METALLURGY, CHEMISTRY,

THE PURPOSE OF THIS PUBLICATION IS TO HELP STATES ORGANIZE AND OPERATE PROGRAMS UNDER TITLE VIII OF THE NATIONAL DEFENSE EDUCATION ACT OF 1958 FOR THE TRAINING OF CHEMICAL AND METALLURGICAL TECHNICIANS. SUGGESTED IS A RATIONALE FOR CURRICULUM DEVELOPMENT WHICH INCLUDES -- (1) IDENTIFICATION OF INDIVIDUAL OCCUPATIONS, (2) ANALYSIS OF JOB CHARACTERISTICS SUCH AS WORK PERFORMED, ABILITY REQUIRED, WORKER CHARACTERISTICS, TOOLS, AND MATERIALS, (3) CLUSTERING OF OCCUPATIONS BY COMMON TRAINING REQUIREMENTS, AND (4) CONSTRUCTION OF A CURRICULUM BASED UPON THE REQUIREMENTS OF THE OCCUPATIONAL CLUSTER TEMPERED BY INSTITUTIONAL CONSIDERATIONS. DESCRIPTIONS ARE GIVEN FOR 11 JOBS IN CHEMICAL AND METALLURGICAL TECHNOLOGIES AND INCLUDE ASSISTANTS, ANALYSTS, AND TECHNICIANS. A JOB FACTOR COMPARISON CHART SHOWS THE CHEMICAL AND METALLURGICAL ACTIVITIES IN EACH OF THE 11 OCCUPATIONS. A TRAINING REQUIREMENTS ANALYSIS FORM IS INCLUDED AS A SPECIMEN OF A METHOD OF DETERMINING CURRICULUM FOR THE TWO TECHNOLOGIES. THIS DOCUMENT IS AVAILABLE AS GPO NUMBER FS 5.280--80016 FOR 25 CENTS FROM SUPERINTENDENT OF DOCUMENTS, U.S. GOVERNMENT PRINTING OFFICE, WASHINGTON, D.C. 20402. (JM)

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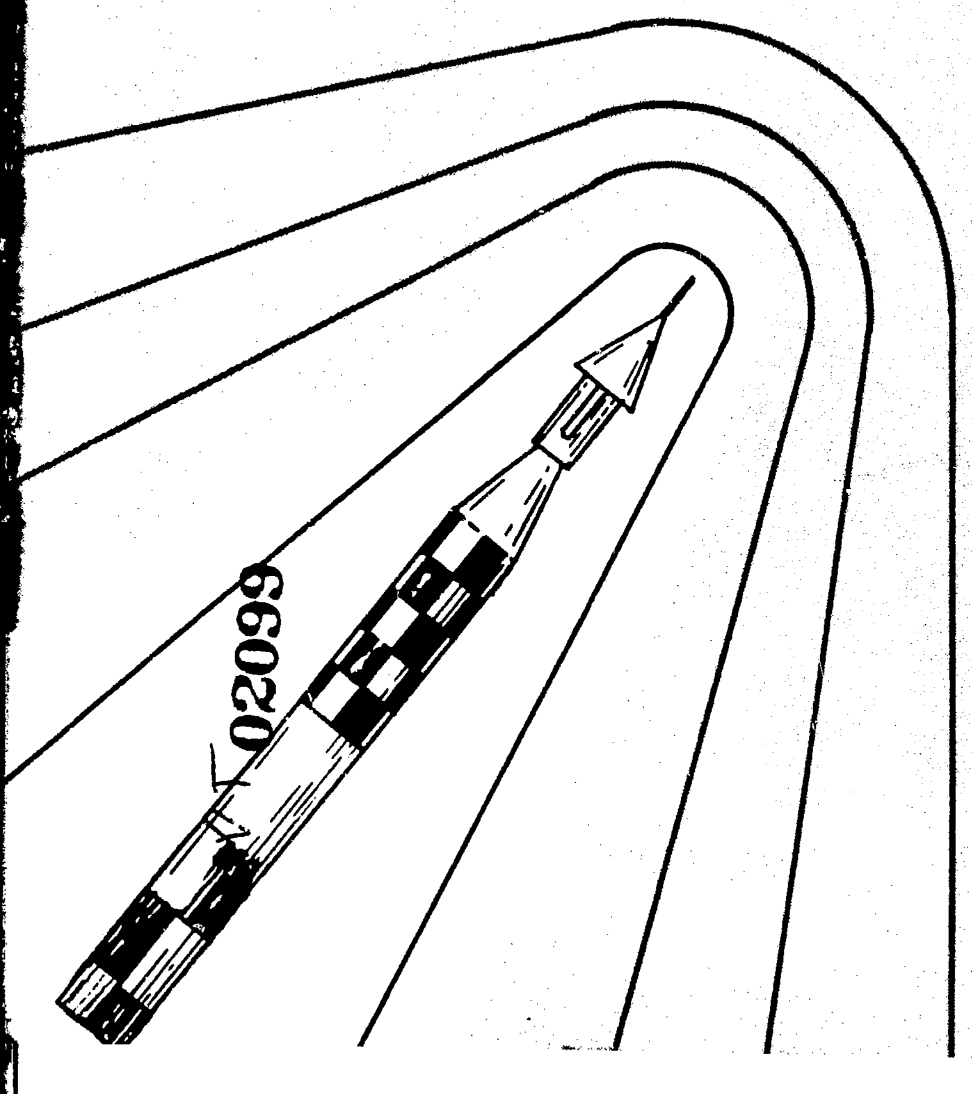
Chemical and Metallurgical Technologies



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U.S. DEPARTMENT OF
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Chemical and Metallurgical Technologies

U.S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
Abraham Ribicoff, *Secretary*
Office of Education, Sterling M. McMurrin, *Commissioner*
Division of Vocational and Technical Education, Area Vocational Education Branch

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FOREWORD

This publication, covering chemical and metallurgical technologies, is the fourth in a series designed to provide information to help the States organize and operate programs under title VIII of the National Defense Education Act of 1958, Public Law 85-864. The other publications are: Mechanical Drafting and Design Technology (OE-80000), Electrical and Electronic Technologies (OE-80004), and Mechanical Technology—Design and Production (OE-80014).

The programs established under this title meet several provisions. Among these are requirements for scientific or technical knowledge, and training in occupational fields necessary for the national defense. Having met the requirements of the act, programs are not precluded because of the occupational titles or classifications under which persons may be employed or because of the segment of industry concerned. For purposes of this document, the terms "technician" and "technical worker" refer to respective scopes of training and work capabilities rather than to employment classifications as such.

Each publication in this series indicates how job analysis and job relationship techniques can be used to facilitate the planning of training programs. Each publication contains the following information and suggestions:

1. General information about a technology or broad field of work
2. A procedure for determining the relationship among jobs in order to develop homogeneous groups or clusters of occupations for which training may be given
3. A method for determining the courses of study required to prepare students for a cluster or group of closely related occupations or for a specific occupation within a group.

The occupations discussed in this document are typical of those found in two broad fields of work, but are not meant to be all-inclusive. They represent typical areas of activity in which technically competent workers are engaged and should not be considered in all cases as entry jobs. Students who have received instruction in an organized training program for a specific technology are provided with the technical knowledge and skills of this field of work, but they usually serve a period of internship in order to learn how to apply their knowledge to technical problems likely to be encountered in the specific job to which they are assigned.

This manuscript was prepared by Clarence E. Peterson, occupational analyst, Area Vocational Education Branch, Division of Vocational Education.

W. M. Arnold,
Assistant Commissioner for
Vocational and Technical Education

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INTRODUCTION

Accurate information about jobs is fundamental to the planning of any occupational training program. The nature of the job information required varies according to the program contemplated. Regardless of its ultimate use, however, the data must be up to date, accurate, and presented in usable form.

The process of obtaining and reporting pertinent information concerning the nature of a specific job is called "job analysis." This technique is used in determining the actions, skills, knowledge, abilities, and responsibilities which are required of a worker for successful performance of his job and in identifying the task or elements which differentiate the job under study from all others.

Basically, there are three parts to the analysis of any job: (a) The job must be completely and accurately identified. (b) The duties and worker actions required in performing the job must be complete and accurate. (c) The knowledge and skills which are required for each job element or task must be specified.

"Job analysis," as used in this document, is not intended to establish a means for determining absolute or relative wage rates, nor is it to be used as a means of establishing seniority groupings or units for purposes of collective bargaining.

After the needs for technical manpower have been determined it will be necessary, in most cases, to analyze the various jobs for which training is contemplated. There are several methods for making a job analysis. Some methods that are widely used are those described in the Training and Reference Manual for Job Analysis, prepared by the U.S. Department of Labor. A recent publication—Handbook for Naval Occupational Analysis—prepared by the Department of the Navy, also contains helpful techniques for analyzing jobs. (*See* Bibliography.)

It is assumed that experienced personnel will be assigned to make the necessary job analyses to provide the basic data which can be translated into curriculums designed to prepare workers for a specific field of work. Therefore, it is not the purpose of this document to describe the methods and techniques for analyzing jobs. Rather, it is the purpose to explain how the basic occupational information resulting from a job analysis study is used to determine the relationship between jobs and the technical knowledge and understandings required for successful job performance. Such information can be used to establish the courses of study required to prepare students for a cluster of closely related jobs or for a specific occupation within a group.

States may not have experienced personnel on their staffs who can devote sufficient time to make the necessary job analyses. The information needed may be available, however, from other sources. In some cases, industry or labor has job analysts who can provide the detailed information about the significant factors of each job or who can make the necessary analyses. Also, the State Employment

Security Agency may have such information in its files or may assign an Occupational Analyst to work with educators in gathering these data.

Because of the specialized nature of technical jobs, it is essential that the data be as detailed and complete as possible. This is especially true of educational and training requirements where the technical knowledge and abilities required for employment in these occupations should be clearly defined. For example, (a) *basic knowledge of chemistry with emphasis on organic and physical chemistry and qualitative and quantitative analysis* is more specific and meaningful than *basic knowledge of chemistry;* and (b) *must have a working knowledge of algebra, trigonometry, analytical geometry, and vector analysis* is more definitive than *uses mathematics in solving electrical problems.*

Most of the information about technical occupations must be obtained through interviews with the worker and his supervisor, with little opportunity for observing the job. Some of these jobs are in areas which are classified for security reasons or the end product may be classified. In such cases, it may be necessary to conduct the interview in a nonclassified area under whatever security regulations may be in effect in the establishment where the study is being made.

A successful training program requires detailed information concerning the nature, duties, responsibilities, job elements, educational requirements, and related factors of each occupation for which training is contemplated. The content of the training curriculum and the selection of trainees depend upon a thorough analysis of each job.

CHAPTER I

THE FIELDS OF WORK

Workers trained in chemical and metallurgical technologies are employed in many industries necessary for national defense, such as the manufacture of ceramics, chemicals, brass and other nonferrous metals, glass, plastics, petroleum products, pharmaceuticals, steel, and textiles. Many are employed in basic research laboratories operated and sponsored by the Federal Government, in educational institutions, and in research laboratories operated by private industry. Others are employed in research and development activities and may assist chemists, chemical engineers or metallurgists in developing new products or in improving existing ones. Some are employed in manufacturing establishments where they follow the materials through processing operations and make tests for process- and quality-control purposes.

There are two distinct types of workers in chemical technology: technical workers who assist research chemists in the laboratory, and those who assist chemical engineers in converting the research chemist's discoveries into actual industrial production. Those engaged in research must be well grounded in chemical analysis, testing, and synthesis; while those concerned with production require knowledge of chemical processing and of the equipment and machinery used for producing chemical products. A chemical technician need not be an expert mathematician, but a good working knowledge of fundamental mathematics is essential.

In some fields, chemical technicians and metallurgical technicians work as a team. For example, in the field of nucleonics, the chemical technician assists in finding new methods for processing fission products, while the metallurgical technician determines materials that can withstand the incredible heat and stress involved in atom-splitting.

While there are no statistics available on the number of chemical and metallurgical technicians needed throughout the Nation, a recent study issued by the National Science Foundation, entitled *Scientific and Technical Personnel in American Industry,* shows that 71,500 chemists and 11,400 metallurgists were employed in American industry in 1959. Fifty percent of the chemists and 40 percent of the metallurgists were engaged in research and development activities; 30 percent of the chemists and 40 percent of the metallurgists were in production and operations. In the same report, it was estimated that the average number of technicians per 100 scientists and engineers in industry was 72. If this average is true of chemical and metallurgical technicians, about 60,000 of them are engaged in these two fields of work.

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Basically the chemical technician and the metallurgical technician require similar educational backgrounds. Both need knowledge of the fundamentals of chemistry, mathematics, and physics. The chemical technician performs tests and makes analyses of inorganic and organic chemicals; the metallurgical technician works with metals and their alloys. While the chemical technician requires only an introduction to and an understanding of the laws of physics, the metallurgical technician must be well grounded in physics and the application of its principles. Conversely, the metallurgical technician requires only an introduction to organic chemistry, while the chemical technician must have a solid foundation in inorganic and organic chemistry.

The *Chemical Technician* works with chemists and chemical engineers in research, development, production, sale, and utilization of chemical products and equipment. The work activities include performing tests and analyses of organic and inorganic materials to determine their composition, structure, and chemical and physical properties. Typical of these activities are: (a) analyzing new or existing materials to determine conformance to standard specifications and to develop additional uses for such materials; (b) performing experiments involving radiation effects on various materials; (c) exposing metal and other specimens to corrosive action under controlled conditions; (d) investigating and developing new methods for purification and crystallization of metals and other inorganic materials; and (e) furnishing quality control data concerning measures of viscosity, refractive indexes, density, and specific gravity.

The *Metallurgical Technician*'s work includes: (a) testing metals for tensile, compressive, or impact strength, creep, stress, rupture, ductility, grain structure, hardness, and internal flaws to obtain data on behavior of metals or to develop metals or metal alloys having certain distinct characteristics; (b) determining the working characteristics of ferrous, nonferrous, and alloy metals to improve such operations as metal forming, casting, welding, rolling, extruding, and drawing; (c) designing and operating special laboratory metallurgical testing equipment, such as thermogravimetric furnaces and cryostats, and adjusting or modifying such equipment to insure optimum functioning and to meet test objectives.

CHAPTER II

JOB RELATIONSHIPS

In developing technical curriculums, the individual occupations for which training is needed should first be identified. Next, an analysis of these jobs should be made, and brief job descriptions should be written, covering the typical work activities, functions, and performance requirements for each occupation.

The occupations should then be arranged in homogeneous groups or clusters, and the kind and amount of basic and applied science, mathematics, and technical "know-how" required to prepare workers to perform the duties of each job should then be specified. Training curriculums which grow out of such analyses and groupings are commonly called "cluster-based" curriculums.

The procedure used to determine similarities and common knowledge and abilities required in various jobs is called job relationship technique. The factors and the criteria used by industry for establishing job relationships vary. However, all or most of the following factors are used in establishing the homogeneous groups or job clusters referred to in this circular:

1. Kind of work performed
2. Abilities and knowledge required of the worker for successful job performance
3. Pattern of worker characteristics required by the job, such as high degree of accuracy, above-average mental application, creative ability, and use of independent judgment
4. Tools, machines, instruments, or other equipment used on the job; reading and interpreting of blueprints, or use of special measuring devices which may be involved
5. Basic material worked on or with. Occupations may involve working with more than one material or working with the same material in different forms.

To establish a cluster of related jobs, similarities within most of these factors should exist. These similarities need not be exactly matched but should be analogous. For example, in developing the relationships of jobs found in the broad field of drafting and design, it is apparent, when using the factors shown above, that the electrical draftsman and the mechanical draftsman have one ability (factor 2 above) in common—that of drawing. The abilities other than manipulative skills and the knowledge required for successful job performance are dissimilar. The mechanical draftsman prepares drawings for mechanical devices. He must know how to calculate such engineering details as strengthweight ratios, tolerances, and elements of

practical machine design. He must be familiar with the working properties of metals, metal alloys, and other materials, as well as with machine shop operations and practices. On the other hand, the electrical draftsman prepares plans and wiring diagrams. His knowledge must encompass electricity and magnetism, circuitry, and other areas related to electrical engineering. Therefore, it is evident that these two jobs are not closely related and do not belong in the same cluster or major grouping. The same conclusions might be reached regarding construction and architectural drafting.

Before a detailed analysis of job characteristics is made, it might seem that the functions of technicians engaged in chemical and metallurgical activities are closely related. Such worker characteristics as high degree of accuracy, above-average mental application, creative ability, and use of independent judgment are common to both fields of work, and also apply to most technical jobs. Both fields of work require knowledge of chemistry and mathematics; both use laboratory apparatus in their work. Yet, a careful analysis of the two occupational categories indicates two distinct fields of work.

The Job Factor Comparison Chart on pages 8, 9 is a suggested procedure for establishing clusters of related jobs by comparing the characteristics or factors of a number of occupations. It should be clearly understood that no attempt is made herein to place a relative value upon any of the factors. The mere quantity of factors associated with a job does not, of necessity, reflect the skill level required.

A preliminary analysis was made of a number of jobs which seemed to belong in the two fields of work under study. The characteristics or significant factors of the jobs under consideration were identified and only those having similar characteristics were used. Of these, 11 jobs were selected for comparison in order to determine their interrelationships. Other jobs might have been included in this list and the ones selected are not meant to be all-inclusive. Those selected merely illustrate how the technique may be used.

The Job Factor Comparison Chart provides a graphic illustration of the relationships among these various jobs. Job factors 1 through 10 are generally considered characteristics of technical occupations in chemical technology, while factors 11 through 16 are found in the field of metallurgical technology. A close look at the chart reveals that at least half of the factors in the chemical activities group (1 through 10) are present in jobs A through F and at least 50 percent of the factors in the metallurgical activities group (11 through 16) are present in jobs G through J. Usually, if less than half of the factors are found to exist in a particular job, the relationship would not be close enough to warrant its inclusion in the cluster or major grouping.

It will be noted that a definite pattern is established on the chart showing clearly that some of the factors are common to each of the jobs under consideration and that at least half of factors 1 through 10 are found in each of the jobs in chemical activities. Similarly, at least half of factors 11 through 16 are found in each of the occupations in metallurgical activities. This pattern indicates that the first six jobs are in chemical technology and the last five belong in metallurgical technology.

CHAPTER III

JOB DESCRIPTIONS

The job descriptions included in this section are given as examples of the kinds of occupations found in the two fields of work described in this publication. It should be clearly understood that these job descriptions are given as examples of closely related jobs for which vocational training can be provided and cannot be considered as standards for the determination of hours, wages, jurisdictional matters, or appropriate bargaining units; or for use in formal job evaluation systems.

The following job descriptions identify and describe the principal duties of each job, and should be useful in identifying technical jobs in the chemical and metallurgical technologies. Also, they may be used for comparison purposes when making analyses of related jobs. In many cases, the plant jobs studied may reveal only minor differences from the job descriptions in this chapter. When this occurs, only the differences in job content and the performance requirements need be considered. In making comparisons, care should be exercised to avoid limiting the content of courses of study to the needs of local industries. Actually, instruction for a technology should be based on *national* industrial needs as well as on local industrial needs.

ASSISTANT CHEMIST, RESINS

Mixes and cooks experimental batches of urea-melamine resins according to specific formulas, following verbal instructions or written request received from chemist to develop a resin having definite properties. Using knowledge of resin chemistry, prepares written work plan for approval by chemist, detailing procedures to be followed and tests to be made. Weighs and mixes ingredients, using laboratory beam balances, flasks and pipettes and mixes formulation in steam heated laboratory or pilot plant cooker. Regulates temperature and controls reaction during cooking process by adjusting valves or by adding reagents to accelerate or delay polymerization of the resins. Draws off samples at predetermined intervals and tests viscosity, using bubble tubes to determine when reaction is complete. Tests cooked resins to determine their chemical and physical characteristics such as clarity, formaldehyde content, curing properties, and compatibility with solvents and additives. Makes spectrophotometric analyses to determine presence of and quantities of phenol, other aromatic compounds or metallic elements by interpreting the readings recorded during the test and by applying simple mathematical formulas involving multiplication and division of decimal fractions. May make qualitative and quantitative analyses of raw materials used in making resins, using such laboratory techniques as titration, filtration or distillation to determine the presence of and quantity of elements or com-

JOB FACTOR COMPARISON CHART

Significant characteristics in:	CHEMICAL TECHNOLOGY				
	Assistant chemist (resins) A	Ceramics analyst B	Chemical technician, radiation C	Control analyst D	L
CHEMICAL ACTIVITIES					
1. Has knowledge of fundamental concepts of inorganic chemistry.					
2. Has knowledge of fundamental concepts of organic chemistry.					
3. Has knowledge of fundamental concepts of physical chemistry.					
4. Understands and follows basic laboratory techniques and procedures in analyzing chemical compounds.					
5. Uses laboratory apparatus and instruments such as pH meter, microscope, electron microscope, and electro-analyzers.					
6. Tests chemical products to determine compliance with specifications.					
7. Tests chemical products in process and recommends changes in formula or processing, if necessary.					
8. Develops new chemical products or processes or improves existing ones.					
9. Makes computations and tabulates and interprets results of tests and experiments.					
10. Determines combination of unit operations required for most effective manufacturing process.					
METALLURGICAL ACTIVITIES					
11. Understands fundamental concepts and principles of metallurgy.					
12. Uses laboratory equipment such as ovens, kilns, auto-claves, pyrometers, X-ray machines, hardness testers, and gas analyzers for testing and analyzing metals and alloys.					
13. Tests ore samples to improve extraction methods.					
14. Develops new or improved techniques for finishing, hardening, welding or brazing metals and alloys.					
15. Develops new alloys to withstand specified environmental conditions and to improve workability of metals in manufacturing operations.					
16. Makes nondestructive tests of metals and alloys and suggests modifications for product improvement.					

CHEMICAL TECHNOLOGY					METALLURGICAL TECHNOLOGY				
...amics ...alyst	Chemical technician, radiation	Control analyst	Laboratory assistant	Research laboratory analyst	Assistant metallurgist	Laboratory technician, foundry	Research laboratory analyst (extractive metallurgy)	Research laboratory analyst (physical metallurgy)	Assistant metallurgist, metal crys-tallization
B	C	D	E	F	G	H	I–1	I–2	J

pounds in test solution. Keeps and maintains records in laboratory notebook of all procedures and tests performed according to prescribed format for the information of the chemist in charge. Prepares written reports on analyses and experimental work as requested.

CERAMICS ANALYST

Plans and performs tests on ceramic products to determine qualities such as resistance to compression, tension or torsion, reaction to heat and chemicals, or any combination of these, using pull-test machines, ovens, screens, and presses. Suggests approaches for additional research.

Procures materials such as carbons, clays, porcelain enamels, carbides, nitrides and borides. Crushes, mixes, forms, and bakes or fires materials, using such laboratory equipment as power crushers and mixers, molds, hydraulic presses, extruders, and crucibles to make experimental items for testing purposes, such as building bricks, firebricks, tiles and insulators.

Develops ceramic coating for metals, considering such factors as strength requirements, expansion rates of metals and coating, fusion temperatures, and binder materials. Sprays ceramic material on metal test panels, fires coated panels in kilns to fusion points, and tests them in ovens to determine temperatures at which coatings burn away from metals. Tests for flexion breakdown on bending machines. Improves qualities of ceramics by recommending changes in fineness of grinds, proportions of binders, firing temperatures, lubricants, and electrolytes. Determines amount and rate of heat emission or absorption of ceramic coatings on metal and ceramic test plates by placing coated plates in emissometer and absorptometer and varying the power supply and the extent of pressure, vacuum, heat, and refrigeration. Prepares graphs of test results.

CHEMICAL TECHNICIAN, RADIATION

Conducts research experiments, such as determining effects of radiation on metals and metal alloys; determining quantities of various chemicals present in radioactive materials; and finding catalysts that will accelerate reformation of slurry gases into ordinary or heavy water coolants in nuclear reactors. Specializations may occur in work performed as follows:

Radiation Chemistry

Sets up laboratory equipment for experiments, basing decisions concerning types of equipment, apparatus, and instruments to be used on knowledge of industrial chemistry and radioactive materials. Devises fixtures and holding devices, radiation shields, and glass, rubber and plastic containers and tubing for fabrication by others.

Conducts chemical experiments on radioactive isotopes and nuclear fuels, working behind lead barriers and using manipulators and observation mirrors as protection against radiation. Takes radiation intensity readings at intervals to determine rates at which radioactive sample specimens degenerate to half life. Analyzes nuclear fuel and radioactive isotopes for uranium content or for radioactivity,

separating components by distillation or other chemical means. Examines specimens under microscope and makes drawings which show microstructure of samples.

Performs corrosion tests on metal alloy specimens which have been subjected to reactor irradiation by exposing them to various gases under controlled pressure and temperature conditions in electric furnaces. Examines specimens under microscope and makes microphotographs to measure extent of corrosive attack and to show grain structures of treated samples.

Radioactive Materials Research

Analyzes materials at specific stages in processes or experiments to determine specific gravity, mol, and other factors indicating quantities of various chemicals present.

Follows established safety procedures for handling, transporting, and storing common acids, bases, salts, radioactive materials, and toxic or explosive chemicals and gases. Installs and calibrates instruments and records data while experiments are in process by direct observation and from test recording instruments.

Analyzes composition of waste materials to determine method of disposal, and suggests new methods for disposal of materials not covered by standard procedures.

Slurry Radiation Research

Analyzes samples of irradiated slurry to obtain data for use by chemists in developing catalysts to be used in recombining gases produced by the decomposition of water in reactors. Weighs, pressurizes, heats, and agitates sample, using laboratory testing equipment and instruments.

CONTROL ANALYST

Performs qualitative and quantitative chemical analyses of process involved in producing synthetic rubber. Tests samples of raw materials to determine that they are within specification limits required for manufacture of desired polymer. Analyzes samples of product intermediates at manufacturing steps so as to supply data to processing personnel by which they may control the reactions involved, to determine whether processing is being performed according to plant specifications, and to solve current production problems. Analyzes samples of finished rubber taken from drier to determine whether quality warrants its release for shipment, using analytical methods to determine percentages, such as acetone extract, heating loss, fatty acid, soap or ash content. Prepares laboratory test reports and checks analyses with specifications or laboratory supervisors. Makes special analyses as necessary. May secure samples used.

LABORATORY ASSISTANT

Makes chemical tests of oils, soaps, textiles, and other materials, and performs related duties under general supervision of a chemist. Makes soap by turning valves to admit caustic, steam, water, and oil in mixing tank, and operating electric mixer. Tests sample of soap for alkalinity and calculates amounts of chemicals to be

added to mixture. Adds correct amounts. Pumps soap to desired storage tanks. Makes tests of oils and soap products. Makes test of grey goods and of dyed goods for stripping (removing dye).

RESEARCH LABORATORY ANALYST, CHEMICAL

Performs laboratory tests for either development of new products, materials, and processing methods, quality control purposes, or for maintenance of health and safety standards.

The following examples are typical of the activities in which these technicians are engaged:

Fluorine Analysis

Analyzes samples of organic materials from localities adjacent to plant to determine fluorine content and the effects of aluminum reduction plant gases on exposed vegetable and animal life. Prepares samples of organic material, such as soils, vegetation, and animal bone by weighing, crushing, grinding, dehydrating, or reducing sample to ash, and prepares chemical stock solutions to be used in analyses. Analyzes prepared sample material employing standard laboratory procedures.

Highway Materials Analysis

Performs chemical and physical tests on materials used in highway construction, such as paints, coals, steel pipe, reflective glass, or weed killers. Typical examples include the following: Tests paints to determine viscosity and volatility, pigment content or drying time; performs tests on steel pipe to determine gages and weight of coatings; performs chemical analysis of sample metal chips to determine presence and amount of other materials, such as manganese or copper; tests coal for heat value, using calorimeter and mathematical formulas to determine B.t.u. value.

Process Analysis

Performs both repetitive laboratory tests and complete analyses of metals, plastics, elastomers, refrigerant gases, oils, paints, porcelain enamels, chemicals, and electroplating solutions. Tests materials used in processing products and those used in plant operations, such as lubricants and coal. Conducts various tests other than routine testing at successive stages of processing to insure uniformity of products, and analyzes new commercially available materials and parts. Uses chemical and metallurgical laboratory apparatus, including such equipment as pH meters, electroanalyzers, carbon and sulfur determinators, and spectrographs.

ASSISTANT METALLURGIST

Assists metallurgist in examining and testing metal samples to determine their physical properties. Conducts routine microscopic examinations of metals and alloys to determine their crystalline structure, porosity, homogeneity, and other characteristics. Prepares photographs of metal specimens, using a photomicroscope; studies and interprets photographs, and complies report of findings. Examines

metal and alloy samples with X-ray, gamma ray and magnetic-flux equipment to detect internal fractures, impurities and similar defects in metals. Tests samples in pressure devices, hot-acid baths and other apparatus to determine strength, elasticity, toughness or other properties of metals.

ASSISTANT METALLURGIST, METAL CRYSTALLIZATION

Conducts experiments pertaining to the production of single crystals of pure metal. Grows single crystal of a metal such as copper starting with small section of 99.999 percent pure copper rod ("seed"), raising it to a temperature of about 100° F. above the melting point of copper in an electric furnace under controlled conditions. Makes periodic temperature measurements during heating cycle. Slowly raises furnace surrounding tube in which seed is enclosed to allow temperature of melted seed to lower gradually from the bottom upward so that the lowermost part of the copper melt will solidify in the form of a sphere. Continues to raise furnace gradually, allowing balance of copper melt to solidify in the form of a stem on the initial seed, thus producing a single crystal of substantially pure copper.

Prepares surface of newly formed crystal for oxidation by polishing flat surface of crystal to produce mirror-like finish. Treats polished surface of crystal electrolytically in an aqueous solution of phosphoric acid to produce a "strain-free surface." Oxidizes surface of crystal in a reaction chamber after all surfaces oxides have been removed by annealing in an atmosphere of hydrogen. Removes oxide film from specimen for electron microscopic examination. Treats specimen electrolytically in an aqueous solution of potassium chloride to dissolve small amount of copper under oxide film, and removes oxide film for further examination. Determines topography of specimen by placing oxide film in vacuum evaporator, and depositing thin film of gold on film to provide contrast so that electron micrographs will reveal surface topography showing how the oxide is formed on the surface. Keeps detailed notes of all experimental procedures followed and results obtained during experiment to be used by chemist or metallurgist.

LABORATORY TECHNICIAN, FOUNDRY

Performs various tests on production samples of iron. Determines temperature of iron melt, using optical pyrometer to compare brightness and color of melt with that of calibrated light within the instrument. Determines amount of carbon by means of chill test or conducts quantitative chemical tests to determine sulphur and carbon content of iron, using standard laboratory equipment and techniques. Tests iron for hardness, using Brinnell tester. Tests molding sand to determine moisture and clay content. Weighs sample of sand, dries it and reweighs it after moisture has been driven off to determine moisture content. Determines clay content of sand by placing sand in jar of water, allowing clay to settle to bottom of jar, and drying and reweighing sample to determine percentage of clay. Determines amount of bending and pressure sample of iron bar will stand by subjecting it to weight pressures and bending, using mechanical bending devices. May compute

test results to rate quality of iron and molding sand or to arrive at corrections for samples which deviate from standards. May recommend changes in melt temperatures and in iron composition to improve product or processing methods.

RESEARCH LABORATORY ANALYST, METALLURGICAL

Extractive Metallurgy: Performs research and conducts tests using methods, techniques, and apparatus pertaining to extraction of minerals from ores. Sets up laboratory equipment and instruments such as ovens, leaching drums, gas cylinders, kilns, vacuum chambers, autoclaves, pyrometers, and gas analyzers, and prepares samples of ores such as copper, cobalt, iron, molybdenum or zinc by crushing, pulverizing, screening, and weighing. Processes ore samples by roasting, leaching, flotation, and treating chemically.

Tests and analyzes alumina ore samples to study techniques in extraction of aluminum oxide from bauxite, and utilization of processing wastes or low grade ore. Weighs, heats, cools, filters, and dissolves ore samples; treats them with chemical reagents, and observes and evaluates effects to determine values and content of aluminum, iron, silicon, and other substances. Tests samples of raw materials; e.g., fluorspar, cryolite, and caustic aluminate solution. Makes qualitative and quantitative chemical analyses on such finished products as calcined and other specific types of alumina and alumina hydrates.

Maintains detailed records of experiments which include narrative reports, graphs, diagrams of equipment used, and flow charts.

Physical Metallurgy: Participates in research including physical and non-destructive testing of metals, alloys and their protective finishes to develop metals and alloys that can withstand specified environmental conditions and manufacturing processes.

Conducts laboratory experiments in joining metals by welding, brazing, soldering, or riveting, using standard or newly designed hand or automatic equipment and different types of flux to determine feasibility of techniques or to try out new equipment and methods. Experiments with new riveting and welding equipment and techniques, and testing rivets made of new alloys.

Studies effects of oxidation on metals, to determine how oxidation was formed and to provide information for development of alloys with higher resistance to oxidation, by chemically removing oxidation film from metal specimen and mounting it for examination under electron microscope.

Develops new or improved finishing techniques for metals, such as processes for anodizing, flame spraying, vapor diffusion, chemical or electrolytic plating. Tests coated metals to determine such factors as resistance to corrosion, high temperature, humidity, or fatigue.

CHAPTER IV

TRAINING REQUIREMENTS

If the purpose of a technical training program is to prepare workers for a single occupation, the content for such a program is derived from the analysis of that specific job. However, inasmuch as most training programs for a specific technology are designed to prepare workers for a cluster of occupations, the content should be derived from analyses of all the jobs in the cluster. In developing job clusters, it is necessary to assemble the occupational data gathered during the job analysis study, compare the elements or characteristics of the various jobs, determine the elements that are common to the several jobs in a group, ascertain the skills and knowledges required for their performance, and develop a reasonably complete list of the skills and knowledge needed for all the jobs in the cluster. From this list, the specific courses of study which make up the curriculum are developed. Instruction for a specific occupation within a given cluster may require greater depth and emphasis on certain aspects of the training than that required for a cluster-based curriculum. This highly specialized training may be given through extension courses after the individual has entered employment and has gained some experience and understanding in his field of work. Methods and procedures for determining requirements for effective extension training programs are described in the Office of Education publication OE–80010, *Determining Requirements for Development of Technical Abilities Through Extension Training.*

The job descriptions contained in chapter III of this publication, augmented by the information gathered through the individual job analyses made by State or local personnel, should provide much of the data needed for determining training requirements. Each job description should be in two parts. The first part should describe the work performed, i.e., what the worker does and why he does it. The second part should cover performance requirements and provide information about the skills, knowledge, and abilities required of the worker in performing the job duties.

The Training Requirements Analysis Form on page 17 illustrates a method for recording the technical knowledge and ability required for each of the clusters of related jobs. The subheadings on the form—"Chemical Technology" and "Metallurgical Technology"—are the major groupings or fields of work for which training is required.

The first column lists the subject matter areas discovered through job analysis as basic in a training program for occupations in each field of work. Other subject matter areas may be found which belong in these two fields of work, because the requirements of these occupations vary from plant to plant, among industries, and

in different parts of the Nation. Determination of the subject matter required for successful performance in the various occupations of a cluster of related jobs depends upon the adequacy of the source data obtained through job analysis and the ability of the person preparing the form to interpret these data.

If the job descriptions resulting from the job analyses indicate that a knowledge or skill in a certain area is essential, the letter "X" should be entered.

The nature of the work and the industry in which a job under study is found usually suggests to an experienced analyst other subjects which might be helpful to a worker in one of the fields of work. In some cases, it may be found that industry supplies training in these areas, and in other instances the limited demand for such skills in the employment market or lack of facilities in the school makes it inadvisable for the school to set up special courses. The completed chart serves the following purposes:

1. Indicates the technical knowledge and abilities needed by workers to perform the duties of various occupations found in a given field of work.
2. Identifies the subject matter areas that are common to the several jobs in a cluster of related jobs.
3. Provides, in convenient form, a list of the subject matter areas and specific courses of study that should be considered when building the training curriculum.

TRAINING REQUIREMENTS ANALYSIS FORM

SUBJECT MATTER AREAS REQUIRED	Chemical Technology	Metallurgical Technology
MATHEMATICS		
Algebra	X	X
Functions & Graphs	X	X
Solution—right & oblique triangles	X	X
Analytic Geometry	X	X
Intro. to Calculus	X	
CHEMISTRY		
General Chemistry (inorganic)	X	
General Chemistry (metals)		X
Qualitative Analysis	X	
Quantitative Analysis	X	
Physical Chemistry	X	
Organic Chemistry	X	
Quantitative Analysis (metals)		X
PHYSICS		
Electricity	X	X
Heat	X	X
Mechanics	X	X
Optics		X
CHEMICAL TECHNOLOGY		
Unit Operations	X	
Instrumental Methods of Analysis	X	
Industrial Stoichiometry	X	
METALLURGICAL TECHNOLOGY		
Physical Metallurgy		X
Principles of Metallography		X
Industrial Instruments		X
Spectroscopy		X
Strength of Materials		X
Non-destructive Testing		X
Heat Treatment of Metals		X
ADDITIONAL KNOWLEDGES & SKILLS		
Foundry		X
Casting Design		X
Refractories & Furnaces		X
Machine Shop Operations		X
Mechanical Drawing		X
Technical Report Writing	X	X

NOTE: This form illustrates a technique for recording subject-matter areas that should be considered in developing a curriculum and it is not intended as a curriculum guide.

CHAPTER V

DEVELOPING THE CURRICULUM

This chapter reviews curriculum designing rather briefly, assuming that the reader is familiar with pedagogical practice and with curriculum building in other areas of education. It also points out some broad aspects of curriculum development as it relates to technical training.

When the field of work for which training is to be provided has been clearly defined, the individual occupations in the cluster of jobs found in the field of work have been analyzed, and the training requirements have been identified, the curriculum and individual courses of study required to prepare students to perform the various job duties may be prepared.

A curriculum may be defined as a systematic group of courses of study designed to prepare persons for a cluster of jobs or for a specific occupation in a given field of work. It is an organized body of content for the training program—all that the school offers for reaching the desired educational goals.

Curriculums can be developed in several different ways. The simplest method is to use the curriculum of another institution without modification. The hazard of such an approach lies in the possibility that the curriculum may not be a good one. Even though it was satisfactory for the original institution, it may not fit into conditions of the institution where it is to be used. Each institution has specific entrance requirements which may vary from State to State and from one institution to another. A second method is to study a number of curriculums from other institutions and to develop from them a composite curriculum embodying the best points of all of them. The difficulty sometimes encountered with this method is that the resultant program is made up of a group of subjects which may not constitute a completely integrated curriculum.

Probably the most effective method is to use the approach outlined in this circular, which depends upon up-to-date analyses of the occupations with which the program is concerned and the development of a curriculum based upon these analyses. As a check against this method, it is usually helpful to study other curriculums for structure and content.

In undertaking the construction of a curriculum based upon job analysis, the first task is to prepare a composite list of all of the knowledges and skills needed for effective performance in the occupations making up the cluster. In the preceding chapter the technique for developing a list of subject matter areas has been described (Training Requirements Analysis Form). The job descriptions in chapter III represent only typical occupations found in these two fields of work and are not meant

to be all-inclusive. Therefore, the fields should be explored further to ascertain what other jobs should be included in the clusters. All of the jobs should then be analyzed and the findings checked against the present lists to determine whether additional subject matter areas are necessary. Thus, a reasonably complete list of items for the proposed curriculums is assured.

A curriculum does not usually include all of the items which appear on the Training Requirements Analysis Form. Students may be expected to have attained certain knowledges and skills previously. If the curriculum is on the post high school level, the admission requirements may specify high school graduation, completion of certain subjects while the student was in high school, or the attainment of satisfactory scores on achievement or aptitude tests. In some cases, the list may include certain items which may be learned after the student is employed.

On the other hand, the curriculum designer may find it necessary to include some items which do not appear on the list found in the Training Requirements Analysis Form. For instance, the job analysis might lead to the conclusion that proficiency in mathematics is not required in the training program because the duties of the job do not involve mathematical calculations. Such a conclusion overlooks the need for mathematics as a learning and communication tool and can adversely influence curriculum and course design. In addition, it may be necessary to include some general education courses such as social science and communication skills.

In theory, one might take the content revealed by the occupational analyses, organize the content into courses, select the methods to be used for instruction, list the equipment needed, plan the space required, set up standards for student admission and for the instructional staff, and determine the length of the program without regard to conditions in the institution in which the program is to operate. This would be an impractical and unrealistic way to construct a curriculum. There are many factors which must be taken into account. For example, the program may be one of several given by a large institution which has established admission standards, a predetermined length of school year and day, available space which may or may not lend itself well to the proposed program, a limited budget, and many other conditions which affect curriculum planning. The curriculum builder, therefore, may have to adapt the elements of a curriculum to meet the needs of the institution and of the students. The curriculum should be sufficiently complete to provide adequate preparation for students to enter any of the occupations of the technology for which they were trained.

After the subject matter areas have been selected for the curriculum, they are divided into groups which become courses. Next, the courses are arranged in a pattern which recognizes psychological learning sequence, time allocation, and the relative importance of each course. Modifications are then made to adjust all of these factors so that the final curriculum is a well balanced and integrated program.

In technical training of the level required for the fields of work described in this circular, the curriculum content should meet the following criteria:

1. The range of course content in preparation for the jobs in the cluster should be consistent with the total time allotted to the training program.

2. The technical content should lend itself to organized instruction.
3. A substantial part of the curriculum should be able to be mastered by a reasonably high proportion of the students who have the necessary educational backgrounds for the technical training provided.
4. The psychological order of learning should be followed to provide spiral teaching of the subject matter.
5. The curriculum content should include technology of the occupational field, sound training in science and mathematics, including *applied* science and *applied* mathematics (applied to the field of work for which training is provided), other applied content such as technical report writing, or other areas which are essential to satisfactory job performance, and general subjects such as communications and social sciences.
6. Mathematics and the physical sciences are key disciplines in all technical study. Therefore, the various areas of mathematics or science should be integrated so that the application of mathematical or scientific principles supplements and supports the specific course work in these areas. In doing this a high degree of coordination is required. This coordination involves the teaching and application of mathematics or science in technical courses concurrent with the more formal instruction in the mathematics or science classes.
7. The relative emphasis to be placed on each subject and the time that should be allotted to each subject should be carefully analyzed so that the courses of instruction are properly integrated and the total curriculum is in balance.

The subject matter areas in the lists of chemical and metallurgical occupations are not arranged as they will appear in a curriculum, but they indicate the areas of knowledge which should be covered. Analysis of these items is an important step in developing a course of study. From this list the curriculum builder should select, after careful analysis, those subjects which are essential to the cluster of occupations and which are practical to include.

A second step is to group the selected items to provide logical arrangement of the subjects, and to determine whether all of the items can be covered adequately within the time limits of the training program.

A third step in curriculum construction is to develop instructional units which will provide the trainee with the learnings needed for employment in the technology. The instructional unit may take the form of a typical task to be performed, principles to be mastered, a laboratory experiment to be carried out, a problem to be solved, a case to be discussed, a drawing to be made, or a malfunction to be analyzed. The type of instructional unit depends upon the educational objectives, the school facilities, and many of the other factors previously discussed.

The techniques described in this publication, together with the chart and forms provide basic information that can be used in organizing curriculums which will meet specific technical training needs in the chemical and metallurgical technologies.

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This is a guide for making occupational analyses in naval installations, but is readily adaptable to civilian occupations. It provides methods for planning a study, collecting the information and preparing job descriptions. A questionnaire form is included together with functional verbs for use in preparing the occupational analysis schedules.

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